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## **Adult age differences in monetary decisions with real and hypothetical reward**

Horn, Sebastian ; Freund, Alexandra M

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## RESEARCH ARTICLE

WILEY

# Adult age differences in monetary decisions with real and hypothetical reward

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## Abstract

Age differences in monetary decisions may emerge because younger and older adults perceive the value of outcomes differently. Yet, age-differential effects of monetary rewards on decisions are not well understood. Most laboratory studies on aging and decision making have used scenarios in which rewards were merely hypothetical (decisions did not have any real consequences) or in which only small amounts of money were at stake. In the current study, we compared younger adults' (20–29 years) and older adults' (61–82 years) decisions in probabilistic choice problems with real or hypothetical rewards. Decision-contingent rewards were in a typical range of previous studies (gains of up to ~4.25 USD) or substantially scaled up (gains of up to ~85 USD per participant). Reward type (real vs. hypothetical) affected decision quality, including value maximization, switching between options, and dominance violations (choices of an option that was inferior to another option in all respects). Decision quality was markedly better with real than hypothetical rewards in older adults and correlated with numeracy in both age groups. However, we found no evidence that reward type affected people's risk preferences. Overall, the findings portray a fairly positive picture regarding the use of hypothetical scenarios to assess preferences: With carefully prepared instructions, people from different age groups indicate preferences in hypothetical scenarios that match their decisions with real and much higher rewards. One advantage of using real rewards is that they help to reduce decision noise.

## KEYWORDS

aging, decision making, gains, motivation, real and hypothetical payoffs, reward, risk preferences

## 1 | ADULT AGE DIFFERENCES IN MONETARY DECISIONS WITH REAL AND HYPOTHETICAL REWARD

Many classic studies in the field of behavioral decision making have used hypothetical scenarios, assuming that they provide an adequate proxy for the decisions people would make when facing

real consequences (e.g., Kahneman & Tversky, 1979). Moreover, a vast majority of these studies have focused exclusively on decisions by younger adults. However, older adults also have to make important financial, political, and health-related decisions, making it critical to consider age-related differences in how well the conclusions from hypothetical scenarios apply to decisions with real consequences.

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Aging is associated with significant changes in cognitive abilities, motivation, and emotion, which affect preferences and decision outcomes (e.g., Bruine de Bruin et al., 2020; Freund & Ebner, 2005; Mata et al., 2011; Mather & Carstensen, 2005). For instance, Tymula et al. (2013) reported that healthy older adults are “strikingly inconsistent” in their choices in comparison with younger adults and concluded that “just as [older adults] show profound declines in cognitive function, they also show profound declines in choice rationality compared with their younger peers” (p. 17143). Moreover, many decisions across the lifespan about well-being and wealth involve risk. In decisions under risk, people choose between options whose outcomes may differ in valence (positive or negative), in magnitudes, and in probabilities (e.g., various medical treatments may differ in their probabilities of positive and negative effects; a financial investment promises to yield a higher but less probable reward than another one). Therefore, lotteries involving probabilistic outcomes can provide a useful test bed to investigate if and how younger and older adults differ in their perception of risk and reward.

In the present research, we investigated differences between younger and older adults in decisions with real and hypothetical monetary rewards that differed in magnitude using a well-established set of risky decision problems (Holt & Laury, 2002). The comparison of real and hypothetical rewards is methodologically and conceptually informative: So far, most studies on aging and decision making have used tasks in which monetary incentives were either low or merely hypothetical (i.e., people's decisions did not have any consequences). It is currently unclear if findings of age-related differences from studies with hypothetical decision scenarios generalize to decision-making scenarios with real and larger monetary rewards. Conceptually, the comparison between real and hypothetical reward effects may also inform us about the relevance of monetary rewards for younger and older adults and how this may affect different aspects of decision making (e.g., people's preferences and the decision quality). In what follows, we briefly review the literature on incentive effects (almost exclusively with students/younger adults), discuss possible age-related differences in decisions with real and hypothetical rewards, and then present our study in which we orthogonally manipulated reward type (hypothetical vs. real) and reward magnitude in younger and older adults.

## 1.1 | Real and hypothetical rewards: Younger adults

In their review of financial incentives effects in experiments, Camerer and Hogarth (1999, p. 7) noted that the assumed role of incentives for human behavior is a “dividing line between economics and other social sciences, particularly psychology.” The authors reported a search in the journal *American Economic Review* (studies between 1970 and 1997) that “did not turn up a single published experimental study in which subjects were not paid according to performance” (p. 31). Hertwig and Ortmann (2001) examined the publications in the *Journal of Behavioral Decision Making*<sup>1</sup> in a 10-year period (from 1988

to 1997). They found that only 48 (~26%) of 186 studies employed financial incentives and that merely 10 studies (~5%) systematically manipulated payment schemes (e.g., payment vs. nonpayment conditions). These numbers highlight the different experimental conventions across scientific fields that reflect different assumptions about the role of incentives for decision behavior (see Hertwig & Ortmann, 2001, for an overview).

On the one hand, economists have commonly assumed that participants invest more effort and work more effectively, if they receive higher monetary reward for better performance. Smith and Walker (1993) surveyed the studies in experimental economics and found that rewards consistently reduced the variance of decision error. A field study using large real monetary outcomes by Binswanger (1980) with farmers in rural India indicated that virtually all participants showed at least moderate risk aversion that tended to increase when rewards were increased. Holt and Laury (2002) found that a sample of younger adults (83% students) and of some middle-aged adults (17% business-school faculty) made similar choices between risky lotteries with hypothetical and real low incentives. However, participants increased their choices of a safer option when incentives were real and high. Several studies from experimental psychology also indicate differential effects of real and hypothetical incentives: Edwards (1953) reported differences in decisions when participants gambled for real money and when participants just imagined what they would do if they were gambling. Siegel and Goldstein (1959) reported that participants' predictions regarding two possible events in a Bernoulli process changed significantly when financial incentives were provided. Slovic (1969) found that undergraduate participants tended to maximize gains when choices among lotteries were hypothetical but were more cautious and focused on loss avoidance when outcomes were real. These and other classic studies suggest that incentives can have profound effects on younger adults' decisions.

On the other hand, researchers in the fields of psychology and behavioral decision making have frequently assumed that participants are in motivational and cognitive states that allow experimenters to collect reasonably representative samples of decision behavior even in the absence of financial incentives. For instance, many investigations in the tradition of the “heuristics and biases” research program have relied on hypothetical decision scenarios. As noted by Kahneman and Tversky (1979, p. 265), “[...] the method of hypothetical choices emerges as the simplest procedure by which a large number of theoretical questions can be investigated. The use of the method relies on the assumption that people often know how they would behave in actual situations of choice, and on the further assumption that the subjects have no special reason to disguise their true preferences.” In line with this, there are also a considerable number of studies that have found only minor or no differences in decision behavior with real and hypothetical incentives. Beattie and Loomes (1997), for example, compared pairwise choices in real and hypothetical lotteries and reported no differences in a sample of students. Some context effects that have been investigated with hypothetical scenarios (e.g., the attraction or decoy effect: adding an inferior option to a choice set

induces changes in preferences for other options) have also been found with real choices (e.g., Simonson & Tversky, 1992). Kühberger et al. (2002) found similar framing effects (people's tendency to avoid risks in positively framed scenarios and to seek risks in negatively framed scenarios) with hypothetical and real choices. Camerer and Hogarth (1999) reported in their review of 74 experiments comparing the behavior of participants who received no, low, or high financial performance-based incentives that the most frequent finding was that the form of incentivization had no effect on mean performance.

Taken together, the findings suggest that the effects of incentives are complex and mixed. Thus, the extreme positions that incentives never make a difference or always affect decision behavior appear untenable (Camerer & Hogarth, 1999). Incentive effects likely depend on characteristics of the task and on the aspects of decision behavior that are studied: Camerer and Hogarth conclude that financial incentives usually reduce variability or noise in responses (cf. Smith & Walker, 1993) and particularly affect performance when attention and mental effort are relevant (e.g., for learning, judgment, and clerical tasks). In contrast, they conclude that in preferential choice and “in the kinds of tasks economists are most interested in, like trading in markets, bargaining in games and choosing among risky gambles, the overwhelming finding is that increased incentives do not change average behavior substantively” (p. 8; see also Locey et al., 2011; Madden et al., 2003; Taylor, 2013). Thus, to gain a better understanding of age-related differences in decisions between probabilistic options, it seems important to systematically compare the role of real and hypothetical incentives (i.e., to follow a “do-it-both-ways” approach; cf. Hertwig & Ortmann, 2001). We are not aware of any empirical attempts that have done so in the area of decision making and aging. In the next section, we discuss if and how real and hypothetical rewards may differentially affect choice patterns and preferences across adulthood.

## 1.2 | Adult age differences in decisions with real and hypothetical rewards

In the current research, we considered two aspects of decision behavior that can be affected by reward, namely, decision quality (value maximization and variability) and people's preferences among probabilistic options. Based on previous research (e.g., Camerer & Hogarth, 1999), it is conceivable that rewards may differentially impact these aspects of decision behavior (e.g., relatively little impact on people's preferences, but possibly larger effects on decision quality and consistency). This impact may also differ with age. Furthermore, we had a secondary interest to explore if reward type and magnitude impact participants' arousal and affective state.

### 1.2.1 | Decision quality

Several studies suggest that older adults make poorer choices among probabilistic options than younger adults (for overviews, see Hess

et al., 2015; Peters et al., 2007; Weller et al., 2011). Specifically, there is evidence that older adults' choices are often noisier, are less consistent, and show more violations of first-order stochastic dominance<sup>2</sup> than younger adults' choices (Tymula et al., 2013). Research with younger adults suggests that choice variability tends to decrease when higher payoffs are at stake. For instance, decision makers may balance the monetary consequences against the effort or cognitive cost of reducing error in their choices (Smith & Walker, 1993). The cost of cognitive engagement may rise with age in response to normative cognitive decline: Given that fluid cognitive abilities (e.g., Lindenberger et al., 1993; Verhaeghen & Salthouse, 1997) and numerical abilities (Peters et al., 2007) decline with age, older adults may have to invest relatively more cognitive engagement in choices between probabilistic lotteries. Lotteries can be viewed as multi-dimensional stimuli that comprise different pieces of information (i.e., probabilities and outcomes; Slovic & Lichtenstein, 1968), whose consideration likely require fluid cognitive and numerical abilities that decrease with age. This implies that older adults might have relatively higher cognitive cost than younger adults to achieve similar levels of decision quality. In line with this proposition, older adults tend to avoid informational complexity in preferential and multi-attribute decisions (e.g., Zilker et al., 2020). Thus, when rewards are merely hypothetical or low (relative to the required cognitive effort), particularly older adults might find the monetary consequences not to be worth the cognitive effort. In contrast, with higher and real rewards, older adults might be more motivated to process the relevant information despite relatively high cognitive costs.

Taken together, these considerations lead to the prediction that the quality of choices between probabilistic options increases with real and high reward, particularly for older adults.

### 1.2.2 | Risk preference

Apart from decision quality, rewards may affect people's preferences. Risk preference (the extent to which people avoid or seek variability in possible outcomes) has been shown to be sensitive to several factors, including the magnitude of reward (e.g., younger adults tend to be more risk-averse when reward is very high; Holt & Laury, 2002). Some studies suggest that older adults are more risk-averse than younger adults in the domain of gains (e.g., Best & Charness, 2015; Tymula et al., 2013; Weller et al., 2011) and typically prefer smaller sure gains over larger riskier gains (Mather et al., 2012). Overall, however, research on aging and risk preferences has yielded mixed findings. One likely reason is that risk preferences vary strongly across tasks and domains (e.g., Figner & Weber, 2011; Mamerow et al., 2016; Reyna, 2011; Roalf et al., 2012; Rolison et al., 2014). For instance, age differences in risk taking emerge in some tasks involving decisions from experience (when outcomes and their frequencies must be learned), whereas younger and older adults often show similar risk taking in decisions from description (when outcomes and probabilities are described, e.g., in monetary lotteries) (Mamerow et al., 2016; Mata et al., 2011). Other task characteristics likely affect

the size of age differences as well (e.g., the number of options in the choice set: Frey et al., 2015; whether one of the options provides a certain outcome: Kellen et al., 2017; Zilker et al., 2020).

Another factor, which has received little attention so far, is the reward structure. Mata et al. (2011) noted in their meta-analysis of age differences in risky choice that participants received performance-contingent payoffs in only 28% of the studies and suggested that “performance-contingent payment in future research could help ensure that any age-related differences found are not due to unclear reward structures or varying effects of hypothetical payoffs” (p. 26). Following this notion, a further aim in the current study was to compare younger and older adults' risk preferences when real and high monetary rewards are at stake.

In decisions from description between probabilistic options, adult age differences in risk taking are not necessarily expected (e.g., Mamerow et al., 2016; Mata et al., 2011). However, could rewards differentially affect risk preferences in younger and older adults? There are two possible scenarios: As one scenario, striving for monetary reward could be less relevant for older than younger adults. On average, older adults have accumulated more wealth in their lives than younger adults (e.g., Davies & Shorrocks, 2000), decreasing the relative value of additional monetary gains. In contrast, younger adults are typically in a life phase in which they have to accumulate resources they can invest into their future (Freund & Riediger, 2001) and to seize opportunities for gain and growth (e.g., Ravert et al., 2019). For example, Freund and Blanchard-Fields (2014) found that younger participants were more likely than older participants to keep money they had earned during an experiment for themselves, whereas older adults were more likely to donate it to a good cause. This scenario implies a relatively stronger change in preferences between hypothetical and real rewards (e.g., increases in risk aversion) for younger than for older adults (i.e., age  $\times$  reward type interactions). Moreover, to the extent that people tend to be more risk-averse when reward increases (Holt & Laury, 2002), one would expect to find effects of reward magnitude on risk taking.

As an alternative scenario, reward type may influence decision quality, but not necessarily people's preferences (see Camerer & Hogarth, 1999). For instance, a few studies have investigated adult age differences in preferential discounting decisions with different types of positive consequences (hypothetical money and real liquid rewards/favorite drinks; Jimura et al., 2011) or negative consequences (electrical shocks; Löckenhoff et al., 2016). Even though Löckenhoff et al. (2016) did not experimentally manipulate hypothetical and real consequences, the pattern of preferential choices across two separate studies with either real or imagined aversive events was similar. Therefore, if younger and older adults are able to anticipate sufficiently accurately how they would behave in actual situations of choice, the pattern of preferences in both age groups with real rewards would also be expected to emerge with hypothetical rewards. Here, we aimed to investigate which of these scenarios accounts best for younger and older adults' monetary choices.

## 2 | THE CURRENT STUDY

To examine the impact of reward type and magnitude on decision quality and preferences across adulthood, we asked participants to make choices between two options with probabilistic outcomes using a well-established set of monetary lotteries as our starting point. This facilitates comparison of the current findings with a wealth of previous research on younger adults' decisions from description. Moreover, both options were of similar informational complexity, which prevents potential confounds in stimulus materials related to age differences in the ability to deal with many pieces of information (e.g., Zilker et al., 2020).

## 3 | METHOD

### 3.1 | Design and sample

The  $2 \times 2 \times 2$  design included the between-subject factor *age group* (younger and older adults), the within-subject factors *reward type* (hypothetical vs. real), and *reward magnitude* (low vs. high). In the hypothetical conditions, participants were instructed to imagine the outcomes as if they played for real money; they were informed about the wins they *would* have received with their randomly selected choice and outcome, but the wins were not actually paid out. In the real reward conditions, people were explicitly informed that they played for real money and received their wins in cash after the study. In the low-reward conditions, possible gains ranged from CHF 0.10 to 3.85 (~0.11–4.25 USD); in the high-reward conditions, possible gains were scaled up by factor 20 and ranged from CHF 2 to 77 (~2.21–85 USD). Each participant completed four rounds, each including 10 binary-choice lottery problems. To avoid experimentally induced wealth effects, all participants started with the hypothetical reward conditions (cf. Holt & Laury, 2002). The order of the low and high rewards was counterbalanced across participants.

Twenty-nine younger adults (20–29 years) and 36 older adults (61–82 years) participated in the study (Online Supplement 4 includes details about sample-size planning). Details about participant characteristics are in Table 1. Scores from cognitive tests and questionnaires with age-group comparisons are in Table 2. As expected, younger adults scored higher than older adults in tests of processing speed and numeracy, whereas older adults scored higher in vocabulary (semantic knowledge) than younger adults. In line with previous research using self-reports of motivational orientation (Ebner et al., 2006), older adults indicated a stronger orientation toward maintenance and avoiding losses in their personal goals than younger adults. There were no age-group differences on other measures ( $0.30 < BF_{s10} < 3$ ). Further details about the test scales are in the Supporting Information.

### 3.2 | Procedure and materials

Between one and three participants per session were seated in separated cubicles in a quiet laboratory room. A trained experimenter then

**TABLE 1** Participant characteristics

	Younger adults	Older adults
Gender		
Male	13	19
Female	16	15
Education level		
Obligatory school	1	0
Vocational training/apprenticeship	0	14
High school/college	18	11
University degree	10	7
Other	0	4
Income		
<39	20	9
40–99	4	20
>99	1	4

Notes: Frequency of participants (n) as a function of sample characteristics. Income = self-reported yearly income  $\times$  1000 in CHF; four younger and three older adults did not provide information about their income, and information about gender from two older adults was unavailable. The age groups did not differ in the distribution of gender [ $\chi^2(1) < 1$ ,  $BF_{10} = .44$ ], but in education level [ $\chi^2(4) = 20.71$ ] and income distribution [ $\chi^2(2) = 15.84$ ],  $BF_{10} > 100$ .

gave standardized instructions for the subsequent decision task that comprised four rounds of lottery choice problems that are frequently used in experimental economics and decision research (Holt & Laury, 2002). The options in the Holt and Laury task differ systematically in expected value and in variability of the outcomes (risk level). That is, the possible outcomes for Option A are less variable than the possible outcomes of Option B (see Table 3). In the first problem of the set (top row in the table), the probability of the high outcome in both options is .10; only persons with extreme appetite for risk would choose Option B. When the probability of the high outcome increases enough (moving down the rows of Table 3), a person would eventually cross over to Option B. For example, a risk-neutral person who intends to maximize expected value would choose Option A in the top four decision problems (#1 to #4) before switching to Option B in the other problems (#5 to #10). Even the most risk-averse person should switch over by decision #10 in the bottom row, because Option B yields a sure outcome that is higher than the sure outcome of Option A.

We closely followed the procedures and instructions described by Holt and Laury: On each round, participants marked on a paper sheet, in any order they wished, which of two options (A or B) they preferred for each of 10 lottery choice problems. After participants had completed their decisions, one decision (out of 10) was randomly selected by rolling a die. Participants were asked to roll the die themselves (by using a dice cup), and this procedure was supervised by a trained experimenter. The experimenter then marked the selected row (decision) on the sheet. In a second step, participants rolled the die again to determine the outcome and reward for the selected

option. The Supporting Information include verbatim instructions and test materials. Each participant completed four different sheets across the four rounds of the decision task. In each round, participants were given no hint to expect additional rounds of the decision task. Participants finally completed questionnaires, a short test battery at a computer, and were debriefed. The achieved gains from the lotteries were paid out in cash at the end of a session (total duration approximately 45 min). The study was in accordance with the guidelines of the institute ethics review board, did not involve any deception, and all participants provided written informed consent. Open data are available at <https://osf.io/rg7tk>.

## 4 | RESULTS

We used Bayesian analysis of variance (BANOVA) to quantify the evidence for the presence or absence of main and interaction effects of the experimental factors *Reward Type*, *Reward Magnitude*, and of *Age Group* on decision behavior (achieved gains, decision quality, risk preferences; the dependent decision variables are in Table 2). The analyses of effects of these predictor variables on decision behavior were based on *model averaging* (Hinne et al., 2020; Wagenmakers et al., 2018). That is, in a first step, the different possible models (including all possible combinations of main and interaction effects on a dependent variable) were computed. In a second step, the evidence for the inclusion (or exclusion) of a specific effect was quantified by comparing the performance of all models that included that effect to the performance of all the models that did not include that effect. The goal of model averaging is to deal with model-selection uncertainty by considering the conclusions from all candidate models, weighted by the plausibility of each model given the data. Detailed lists for each effect and dependent variable are in Tables S1–S10. In the following analyses, we report the estimated sizes of an effect ( $\eta_p^2$ ) and Bayes factors ( $BF_{\text{inclusion}}$ ) to quantify the strength of evidence in the data for the inclusion of that effect averaged across models (conversely,  $BF_{\text{exclusion}} = 1/BF_{\text{inclusion}}$  quantifies the evidence for exclusion of an effect). We follow conventional practices in our interpretation of  $BF$ s.<sup>3</sup> All analyses used vaguely informative reference specifications of prior distributions.<sup>4</sup>

### 4.1 | Achieved gains

Overall, younger and older adults did not differ in achieved monetary gains after the study ( $M_s = 48$  and 49 CHF, respectively). Further analysis of effects only supported inclusion of the factor *Reward Magnitude*. That is, people expectedly achieved more gains in the high- than low-reward conditions ( $BF_{\text{inclusion}} > 100$ ). However, neither age group nor any of the other experimental factors or their interactions affected gains; there was even moderate evidence for the null hypothesis (no effect on decision-contingent gains), suggesting the exclusion of any further factors ( $6.05 > BF_{\text{exclusion}} > 3.74$ ).



**TABLE 2** Cognitive, motivational, and decision-task variables

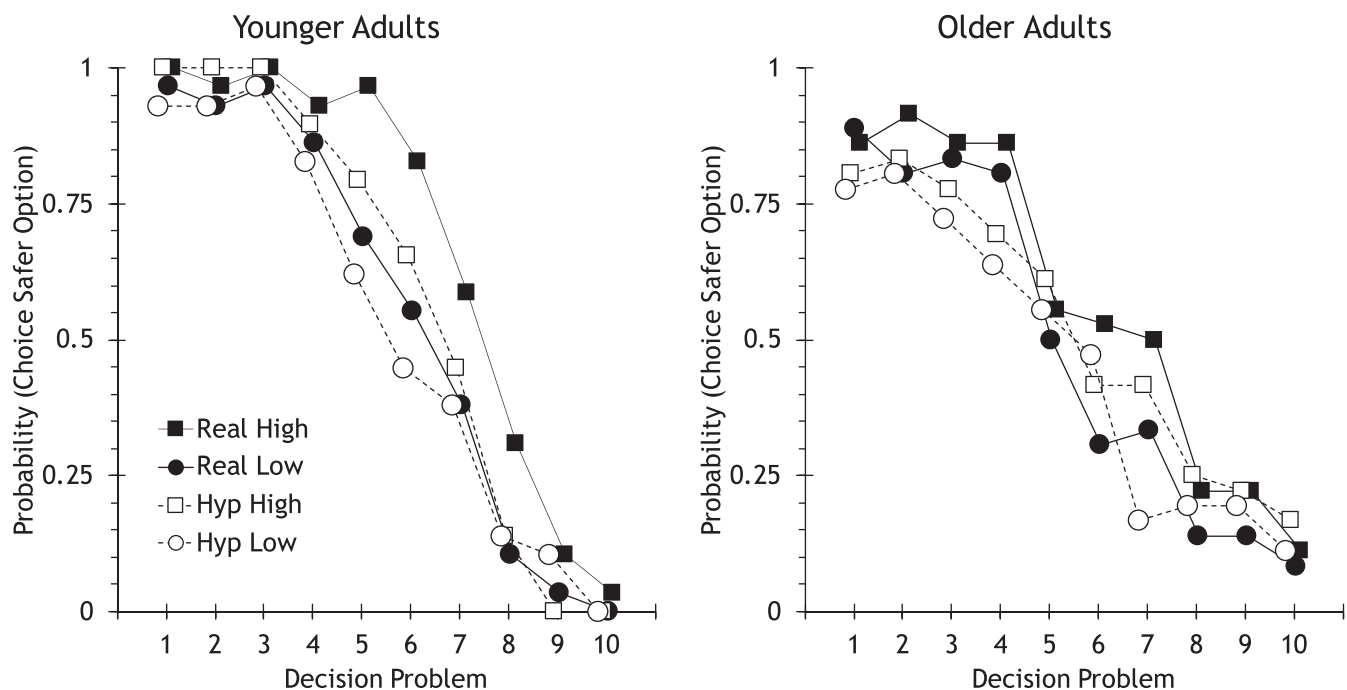
	M		SE		BF <sub>10</sub>
	Younger adults	Older adults	Younger adults	Older adults	
Age (years)	23.83	70.14	.49	1.11	
Numeracy (0–11)	9.82	7.67	.22	.50	41.64
Vocabulary (0–93)	29.97	32.83	.46	.36	>100
Cognitive speed (0–93)	41.83	24.53	1.20	.74	>100
Health (1–7)	5.59	5.33	.21	.18	0.36
Life satisfaction (1–7)	5.69	5.56	.17	.15	0.30
Reported risk taking (1–11)	5.86	6.36	.43	.31	0.38
Gain orientation (1–8)	6.83	6.39	.24	.25	0.49
Maintenance orientation (1–8)	5.10	6.18	.30	.30	3.54
Loss orientation (1–8)	4.40	6.56	.44	.27	>100
Decision quality: EV-max.					
Hypothetical, low	.80	.73	.03	.03	0.66
Hypothetical, high	.79	.70	.02	.03	1.30
Real, low	.80	.78	.03	.03	0.27
Real, high	.71	.74	.03	.03	0.31
Decision quality: noise					
Hypothetical, low	.13	.27	.02	.04	6.70
Hypothetical, high	.12	.29	.01	.04	71.44
Real, low	.12	.18	.02	.02	1.64
Real, high	.13	.22	.02	.03	1.87
Risk aversion					
Hypothetical, low	.53	.46	.04	.03	0.66
Hypothetical, high	.59	.52	.03	.03	1.04
Real, low	.55	.48	.04	.03	0.55
Real, high	.67	.56	.03	.03	3.47
Affect (1–9)					
Hypothetical, low	7.17	6.92	.19	.28	0.32
Hypothetical, high	7.31	7.06	.21	.26	0.32
Real, low	7.24	7.56	.20	.25	0.37
Real, high	7.55	7.75	.23	.27	0.29
Arousal (1–9)					
Hypothetical, low	3.31	3.92	.34	.38	0.45
Hypothetical, high	3.76	4.14	.39	.41	0.31
Real, low	3.41	4.22	.33	.45	0.57
Real, high	4.21	4.56	.43	.44	0.29
Achieved total gains (in CHF)	47.84	48.79	3.87	4.55	0.26
Gains hypothetical, low	2.43	2.09	.24	.23	0.39
Gains hypothetical, high	46.59	50.86	4.05	4.60	0.31
Gains real, low	2.25	2.56	.23	.19	0.41
Gains real, high	45.59	46.22	3.89	4.53	0.26
Proportion of gains donated	.21	.29	.04	.05	0.45

Notes: For rating and test scales, minimum and maximum possible values are in parentheses in the left column; EV-max. = proportion of choices (out of 10) of lottery with higher expected value; decision noise = proportion of switches (out of 9) in the decision task; risk aversion = proportion of choices (out of 10) of lottery with lower outcome variability; achieved gains = total earnings from the decision task in CHF (1CHF ~1.10 USD); a participant strictly following expected-value maximization would be expected to gain 55.53 CHF on average; affect and arousal were measured after each decision phase with the self-assessment manikin scales; BF<sub>10</sub> = evidence that the age groups differ on a given variable; further details about test scales for vocabulary, cognitive speed, numeracy, and motivational orientation are in the Supporting Information.

**TABLE 3** Characteristics of the choice problems presented to participants

#	Option A	Option B	EV <sub>A</sub>	EV <sub>B</sub>	SD <sub>A</sub>	SD <sub>B</sub>	CV <sub>A</sub>	CV <sub>B</sub>
1	40, 0.1; 32, 0.9	77, 0.1; 2, 0.9	32.8	9.5	2.4	22.5	7.3	236.8
2	40, 0.2; 32, 0.8	77, 0.2; 2, 0.8	33.6	17.0	3.2	30.0	9.5	176.5
3	40, 0.3; 32, 0.7	77, 0.3; 2, 0.7	34.4	24.5	3.7	34.4	10.7	140.3
4	40, 0.4; 32, 0.6	77, 0.4; 2, 0.6	35.2	32.0	3.9	36.7	11.1	114.8
5	40, 0.5; 32, 0.5	77, 0.5; 2, 0.5	36.0	39.5	4.0	37.5	11.1	94.9
6	40, 0.6; 32, 0.4	77, 0.6; 2, 0.4	36.8	47.0	3.9	36.7	10.6	78.2
7	40, 0.7; 32, 0.3	77, 0.7; 2, 0.3	37.6	54.5	3.7	34.4	9.8	63.1
8	40, 0.8; 32, 0.2	77, 0.8; 2, 0.2	38.4	62.0	3.2	30.0	8.3	48.4
9	40, 0.9; 32, 0.1	77, 0.9; 2, 0.1	39.2	69.5	2.4	22.5	6.1	32.4
10	40, 1.0; 32, 0.0	77, 1.0; 2, 0.0	40.0	77.0	0.0	0.0	0.0	0.0

Notes: Option pairs for each of the 10 choice problems used in the study, with each option ( $x_1, p_1; x_2, p_2$ ) offering outcome  $x_1$  with probability  $p_1$  and outcome  $x_2$  with probability  $p_2 = 1 - p_1$ . The table shows the outcome values for the high-reward condition (paid out in cash in CHF; 1 CHF  $\sim$  1.1 USD); in the low-reward condition, all outcome values  $x_i$  were scaled down:  $x_{i\text{low}} = \frac{1}{20}x_{i\text{high}}$ . Abbreviations: CV, coefficient of variation,  $CV = \frac{SD}{EV} \times 100$ ; EV, expected value; SD, standard deviation of outcomes.

**FIGURE 1** Proportion of choices of the safer Option A as a function of decision problem, age group, and condition. A decision maker who maximizes expected value would choose the safer Option in decision problems #1 to #4 and then switch to the riskier Option B in problems #5 to #10. Younger and older adults were sensitive to expected value and tended to avoid risk. The 10 decision problems are listed in Table 3

## 4.2 | Decision quality: Value maximization

Next, we analyzed the frequency with which participants chose the option in a decision problem with the highest expected value  $EV = \sum x_i p_i$  (where  $x_i$  and  $p_i$  are the amount of money and probability, respectively, associated with the outcomes of that option). Value maximization has been used frequently as a benchmark to assess the quality of people's decisions under risk (e.g., Dhami et al., 2011;

Pachur et al., 2017; Tymula et al., 2013). As can be seen in Figure 1, participants' choices were clearly sensitive to EV: The probability of choosing the safer Option A dropped systematically with increasing attractiveness of the alternative Option B (Table 3 lists the EVs of both options).

However, the effects of the experimental manipulations on value maximization were relatively subtle, in line with the observation that both age groups gained similar monetary amounts. Nonetheless, as



Table 2 indicates, older adults' decision quality was descriptively lower than younger adults' in both hypothetical reward conditions, but not in both real reward conditions. Real rewards tended to enhance older adults' decision quality more than younger adults'. In line with this, an analysis of effects with BANOVAs indicated moderate evidence for an Age  $\times$  Reward Type interaction ( $BF_{\text{inclusion}} = 4.34$ ,  $\eta_p^2 = .09$ ). The evidence for any further effects was either ambiguous or supported their exclusion ( $6.37 > BF_{\text{exclusion}} > 0.37$ ).

### 4.3 | Decision quality: Noise

Next, we analyzed people's switches between safer and riskier options in the presented set of choice problems as an indicator of decision noise. If participants have monotonic preferences, they prefer the safer option up to a certain level and then switch to preferring the riskier option in all subsequent rows in the choice table (Table 3). In line with previous research, the majority of participants chose the safer Option A when the probability of the higher reward was small and then crossed over once to Option B when the probability of the higher reward increased, without switching back to Option A. However, some participants switched several times between safer and riskier options in the set of choice problems, indicating noise or stochasticity in decision making (Holt & Laury, 2002). Table 2 shows the proportions of switches as a function of age group and condition. Analyses of effects indicated that older adults made more volatile choices than younger adults,  $BF_{\text{inclusion}} = 30.53$ ,  $\eta_p^2 = .16$ , and switched more frequently between safer and riskier options in their decisions. This dovetails with previous research, indicating age-related increases in stochasticity in decision making (Tymula et al., 2013). Notably, there was also evidence for effects of Reward Type ( $BF_{\text{inclusion}} = 22.47$ ,  $\eta_p^2 = .17$ ) that were qualified by an Age  $\times$  Reward Type interaction ( $BF_{\text{inclusion}} = 15.11$ ,  $\eta_p^2 = .17$ ). Older adults switched more frequently than younger adults in the hypothetical reward conditions; this was not the case in the real reward conditions. Evidence was either ambiguous or supported exclusion of any further effects ( $4.56 > BF_{\text{exclusion}} > 2.35$ ).

Even though the level of stochasticity was higher in older than younger adults' choices, this does not mean older adults were behaving at random or failing to understand the situation they encountered. If participants behaved at random, they would choose the two options with equal probability of .50 and be insensitive to reward magnitudes and outcome probabilities. This was clearly not the case: Both younger and older adults' choice probabilities in the decision problems deviated substantially from .50 (all  $BFs > 100$ ), except for the decision problems around the switching point (problems #5 to #6).

We further examined people's choices when one option was objectively better than the other (i.e., in decision problem #10, in which both options offered a sure outcome without any trade-offs between value and probability). Although experimental research shows that people do not always choose stochastically dominant lotteries (e.g., Kahneman & Tversky, 1979), little is known about age-related differences in dominance violations. In the current study, there

was evidence for age differences in the frequency of dominance violations,  $\chi^2(1, N = 65) = 5.73$ ,  $BF_{10} = 7.03$ . We found that 25% of the older adults chose a lower valued option (in at least one of the four conditions) that was dominated by a higher valued option; in contrast, only 3.45% of the younger adults showed such violations. In line with previous research (Tymula et al., 2013), this suggests that dominance violations increase with age.

### 4.4 | Risk preference

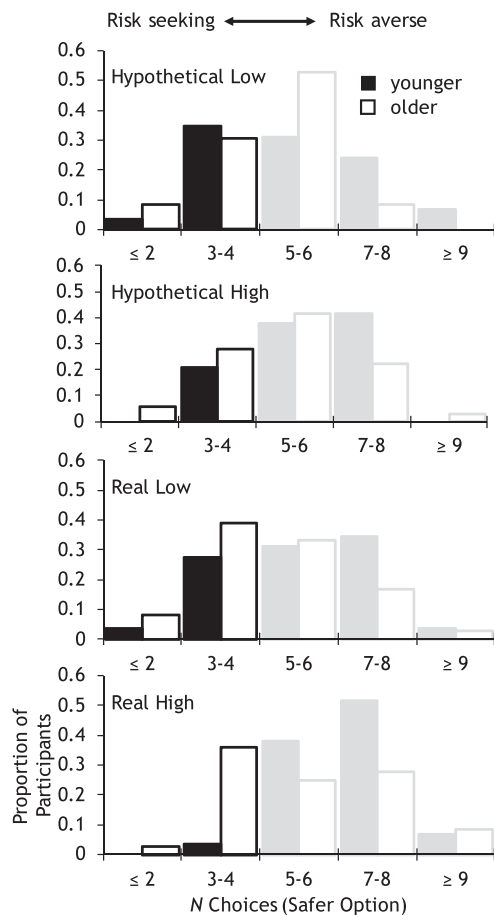
To quantify risk aversion (a decision maker's distaste for options with higher variability in possible outcomes), we analyzed the proportion of choices of safer options among the presented problems (Holt & Laury, 2002). Figure 1 shows the proportion of choices of Option A (whose outcome variability was always lower than that of Option B) as a function of decision problem, experimental condition, and age group. A decision maker who maximizes expected value would choose the safer Option A in choice problems #1 to #4 and choose the riskier Option B in problems #5 to #10. (Figure 2 shows the distributions of participants over the number of safer option choices).

Analysis of effects showed that there was very strong evidence for an effect of reward magnitude on risk aversion,  $BF_{\text{inclusion}} > 100$ ,  $\eta_p^2 = .19$ , indicating that people chose the safer option more frequently when rewards were higher (CHF 2–77) than lower (CHF 0.10–3.85). The evidence was only equivocal or supported exclusion of further main effects or interactions in the models ( $4.79 > BF_{\text{exclusion}} > 0.33$ ). Despite these experimental manipulations, there was also evidence for moderately high rank-order stability of people's risk aversion across the four conditions (rounds) of the decision task (with rank-correlation coefficients  $\tau$  ranging from .27 to .49; all  $BF_{s10} > 19$ ), suggesting that people who chose safer options more frequently than riskier options in one round also tended to do so in the other rounds (Supplement 5 includes further details).

### 4.5 | Affect and arousal

After each round of decisions, participants provided ratings of their current affective state (1 = *very negative*; 9 = *very positive*) and arousal (1 = *very calm*; 9 = *very excited*). We were thus able to explore to what extent the experimental manipulations of reward type and reward magnitude might influence participants' reported affect and level of activation. These analyses, however, were exploratory, and we did not formulate specific hypotheses in advance.

Regarding affect, analysis of effects indicated that the type of reward influenced the ratings: Participants reported higher positive affect<sup>5</sup> in the real than hypothetical conditions,  $BF_{\text{inclusion}} > 100$ ,  $\eta_p^2 = .15$ ; there was no evidence for further effects,  $4.82 > BF_{\text{exclusion}} > 0.45$ . Regarding arousal, people reported higher ratings when rewards were high than low,  $BF_{\text{inclusion}} = 27.96$ ,  $\eta_p^2 = .18$ ; there was no evidence for further effects,  $4.76 > BF_{\text{exclusion}} > 0.38$ .



**FIGURE 2** Proportion of younger adults (filled bars) and older adults (unfilled bars) classified as risk-seeking (black) and risk-averse (gray) as a function of experimental condition. The number of choices of the safer option increased in both age groups in the high-reward conditions

#### 4.6 | Relations with cognitive variables

Finally, we explored the relations between the decision variables (i.e., decision quality, decision noise, risk preferences, and achieved gains) and further cognitive and motivational variables that we collected in tests and questionnaires after the decision task. We did not find systematic correlations, except between numeracy and indicators of decision noise (switching between options and dominance violations). That is, for younger adults, we found negative correlations between amount of switching and numeracy in three of the four experimental conditions (smallest  $r > .49$ , smallest  $BF_{10} > 7$ ) and for older adults in all conditions (all  $r > .44$ , all  $BF_{10} > 7$ ). Further correlational path analyses with both numeracy and cognitive speed as indicators of fluid cognitive ability suggested that numeracy scores (but not speed scores) could statistically account for the age-related differences in switching (see Supplement 2). Moreover, participants' frequency of dominance violations was associated with their scoring (below vs. above 50% correct) in the numeracy test,  $\chi^2(1, N = 65) = 23.68$ ,  $BF_{10} > 100$ .

## 5 | DISCUSSION

The current study systematically compared age-related differences in choices between options with real and hypothetical probabilistic reward of low and high magnitude. Younger and older adults did not differ in achieved earnings and expected-value maximization. However, in line with previous research (e.g., Tymula et al., 2013), older adults' choices were less consistent than younger adults'. Numerical abilities (scores in a numeracy test) correlated with these decision inconsistencies.

Overall, there was more evidence for the equivalence of real and hypothetical reward effects on the decisions by younger and older adults. Importantly, however, older adults' decision inconsistencies decreased markedly when real rewards were at stake. In particular, real rewards reduced switching between options and dominance violations in older adults, whereas younger adults showed similarly low levels of decision inconsistencies across the different reward conditions. At the same time, we found typical age differences in test scores of cognitive speed and of numeracy (Table 2), which correlated with decision quality. This pattern is in line with the idea that older adults have more difficulties than younger adults to process the relevant information in decisions under risk—which mainly affects their decision quality and not their preferences (cf. Olschewski et al., 2018, for evidence that cognitive-load manipulations predominantly affect choice consistency rather than preferences). Therefore, one interpretation of this finding is that due to age-related decline in fluid and numerical abilities (Lindenberger et al., 1993; Peters et al., 2007), reducing errors in probabilistic choices requires more effort for older than younger adults and that older adults invest the additional effort only when real rewards are at stake. Thus, rewards might have provided a form of compensation for older adults' relatively higher effort cost (cf. Smith & Walker, 1993) to reach similar levels of decision quality as younger adults.

Regarding risk preferences, we found only an effect of reward magnitude: Both younger and older adults chose safer options more frequently when rewards were higher than lower (cf. Holt & Laury, 2002). The lack of age-related differences in risk taking (with simultaneous age differences in numeracy and processing speed) in the current study is consistent with previous findings, suggesting that age differences in probabilistic choice depend on characteristics of the decision task and the stimuli. For instance, several studies have also found no age differences in decisions from description under risk (e.g., Mamerow et al., 2016; Mata et al., 2011), particularly for choices between options of similar complexity (Zilker et al., 2020). Notably, participants' risk taking in the current study did not change when real rewards were provided instead of hypothetical rewards. This bears a striking resemblance to findings by Kühberger et al. (2002) on the framing effect in risky choice with real and hypothetical rewards. In one of the few experiments so far that systematically compared reward type and magnitude in a sample of younger adults, Kühberger et al. (2002) found that the framing effect depended on reward magnitude for real rewards, whereas participants' hypothetical choices matched real choices for low and high rewards. The current study

revealed a similar pattern for younger and older adults' risk preferences as a function of reward type and magnitude. This highlights the importance of distinguishing between the reality status (real vs. hypothetical) and the magnitude of reward, which are often confounded in the literature, but may affect choice differentially.

The lack of an effect of reward type may appear surprising, because the rewards offered in a hypothetical scenario are only imaginary. One explanation is that the magnitude of reward primarily affects the anticipation process of future outcomes, which is relevant for both hypothetical and real choice. Kühberger et al. (2002) noted that decision making could be viewed as "hypothetical in its very core" (p. 1163) because any outcomes are present only as hypothetical future events at the time a choice is made. The current findings suggest that both younger and older adults are able to anticipate reasonably accurately in hypothetical scenarios how they behave in actual scenarios of choice. This does not imply that decisions in general can be studied hypothetically with satisfactory external validity, because the anticipation of future outcomes is only one aspect in the decision process. Whereas a decision maker's state remains unaffected in hypothetical scenarios, real rewards will change the state of a person at some point. It is conceivable that knowledge of this difference affects further aspects of decision making. For instance, the present findings show that reward type does not necessarily affect the preferences that people express, but it may affect the variability and consistency of their choices.

## 5.1 | Limitations and outlook

To take a first step to systematically compare the effect of real and imagined rewards on younger and older adults' decisions and to facilitate comparisons with the majority of previous studies on decisions under risk, we focused on monetary outcomes (Holt & Laury, 2002) in the present experiment. As a potential limitation, it remains unclear to what extent the findings generalize to decisions with nonmonetary outcomes (e.g., Lejarraga et al., 2016; von Helversen et al., 2020) and other types of decision tasks. Regarding risk taking, for instance, we found medium-sized rank correlations across the different experimental conditions in our study, in line with the notion that people have moderately stable risk-taking propensities (e.g., Frey et al., 2017; Josef et al., 2016). However, multimethod investigations of risk-taking behavior have also found substantial task-specific variance in decision behavior, challenging the view that people's preferences can be stably measured across different behavioral tasks (Pedroni et al., 2017). There is also aging research suggesting that younger and older adults' preferences may vary across different decision tasks: Seaman et al. (2018) compared three types of discounting decisions (effort, probability, and time discounting) and found no correlations across tasks in people's discount rates; Jimura et al. (2011) found that young adults discounted hypothetical monetary rewards more steeply than older adults, but this pattern reversed with consumable liquid rewards, indicating that the type of reward may differentially affect preferences as a function of age. Such

findings raise important questions about the utility of monetary incentives across adulthood compared with other nonmonetary incentives. In the current study, we found no evidence that monetary outcomes were less relevant for older than younger adults; nonetheless, it remains an important research endeavor to better understand how the utility of different incentives may change across adulthood due to changes in motivational orientation (Freund & Blanchard-Fields, 2014; Horn & Freund, 2021; Mayr & Freund, 2020; Ravert et al., 2019). Given that hypothetical and real rewards may come in many forms, it is an interesting avenue for further investigations to compare their effects across different types of decisions and outcomes.

## 5.2 | Conclusion

The present research aimed to delineate effects of reward magnitude and type (real vs. hypothetical) on younger and older adults' monetary decisions, following a "do-it-both-ways" approach (Hertwig & Ortmann, 2001). The findings highlight the need to distinguish between the reality status and magnitude of rewards and show that rewards can differentially impact aspects of choice behavior: Real and high rewards improved older adults' decision quality; in contrast, both younger and older adults' risk preferences showed a similar pattern across hypothetical and real scenarios. This is in line with the notion that reward may particularly affect those aspects of decision behavior that benefit from increased effort or attention (e.g., decision quality), whereas reward may not necessarily shift people's preference (Camerer & Hogarth, 1999). Taken together, the current findings portray a fairly optimistic picture regarding the use of hypothetical scenarios to study monetary decisions. With carefully prepared instructions in hypothetical scenarios, people from different age groups indicate preferences that generalize to situations with real rewards. Nonetheless, rewards may help to improve decision quality (reduction of decision noise/variability), which correlated with numerical abilities in the present study.

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## ENDNOTES

<sup>1</sup> Samples from the journals *American Economic Review* and *Journal of Behavioral Decision Making* were chosen by the authors of these reviews (Camerer & Hogarth, 1999; Hertwig & Ortmann, 2001) because they

were perceived as reasonably representative outlets reflecting the experimental practices at that time by economists and behavioral decision researchers, respectively.

<sup>2</sup> Stochastic dominance refers to an order between random variables, where one lottery (i.e., a probability distribution over possible outcomes) can be ranked as superior to another lottery. For example, if 1 USD is added to one or more outcomes of a given lottery, the new lottery dominates the old lottery because it yields higher payoff, regardless of specific numbers realized by that lottery.

<sup>3</sup> A Bayes factor (BF) compares the likelihood of the data under one model  $M_1$  (e.g., a model assuming a relation between two variables) to that under another model  $M_0$  (e.g., a model assuming no such relation). BF thus quantifies the degree to which the obtained data should change one's prior beliefs about these models. The subscript in the Bayes factor notation indicates the model supported by the data:  $BF_{10}$  indicates the Bayes factor in favor of  $M_1$  over  $M_0$ , whereas  $BF_{01}$  ( $BF_{01} = 1/BF_{10}$ ) indicates the Bayes factor in favor of  $M_0$  over  $M_1$ .  $BF_{s10}$  larger than 10 or 100 are usually interpreted to indicate "strong" or "extreme" evidence for  $M_1$ , respectively; conversely,  $BF_{s10}$  smaller than 0.1 or 0.01 would indicate "strong" or "extreme" evidence, respectively, for the null model  $M_0$ ; BFs between 1/3 and 3 are usually interpreted to indicate only equivocal evidence (for further details, see Wagenmakers et al., 2018).

<sup>4</sup> Our prior distributional assumptions for the BANOVA models followed default reference specifications (Wagenmakers et al., 2018). That is, for the calculation of Bayes factors for fixed effects, we relied on the common Jeffreys–Zellner–Siow scheme that assumes a multivariate Cauchy prior distribution (because we did not include random effects or covariates in our models, only the specifications for fixed effects are relevant). Specifically, the width (scaling parameter) of the Cauchy prior was set at  $r_A = .5$ , which can be viewed as a default reference analysis in BANOVA models (e.g., Schönbrodt et al., 2017). To assess the robustness of our results and the sensitivity to different prior distributional assumptions, we also repeated the analyses with two further Cauchy prior specifications:  $r_A = 1/\sqrt{2}$  and  $r_A = 1$ . The Bayes factors from these additional analyses are reported in Supplement 6 and led to conclusions that were not qualitatively different from the analyses reported in Section 4.

<sup>5</sup> We also examined whether the achieved gains in a given round (condition) correlated with subsequent ratings of affect and arousal at the end of that round. We found a positive rank correlation between achieved gains and affect for both younger adults ( $\tau = .41$ ,  $BF_{10} = 25.60$ ) and older adults ( $\tau = .30$ ,  $BF_{10} = 5.60$ )—but only when rewards were real and high (evidence for correlations between gains and affect or arousal was inconclusive in the other conditions). Moreover, the correlations among ratings of affect (all  $\tau > .34$ ,  $BF_{s10} > 100$ ) and among ratings of arousal (all  $\tau > .66$ ,  $BF_{s10} > 100$ ), respectively, were all positive, suggesting that people who provided high ratings in one round also tended to provide high ratings in the other rounds of the decision task.

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## SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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